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MEMORANDUM FOR PRS (In-House Publication)

FROM: PROI (STINFO) 19 May 2001

SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-VG-2001-145**
Rusty Blanski, Shawn Phillips, "Status of the Air Force Solid Rocket Motor Insulation Program"

50th Annual JANNAF Propulsion Conference **(Statement A)**
(Salt Lake City, UT, 11-13 July 2001) (Deadline: PAST DUE!)

1. This request has been reviewed by the Foreign Disclosure Office for: a.) appropriateness of distribution statement, b.) military/national critical technology, c.) export controls or distribution restrictions, d.) appropriateness for release to a foreign nation, and e.) technical sensitivity and/or economic sensitivity.
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_____

PHILIP A. KESSEL Date
Technical Advisor
Space and Missile Propulsion Division

Status of the Air Force Solid Rocket Motor Insulation Program

11 July 2001

Dr. Rusty Blanski

AFRL/PRSM

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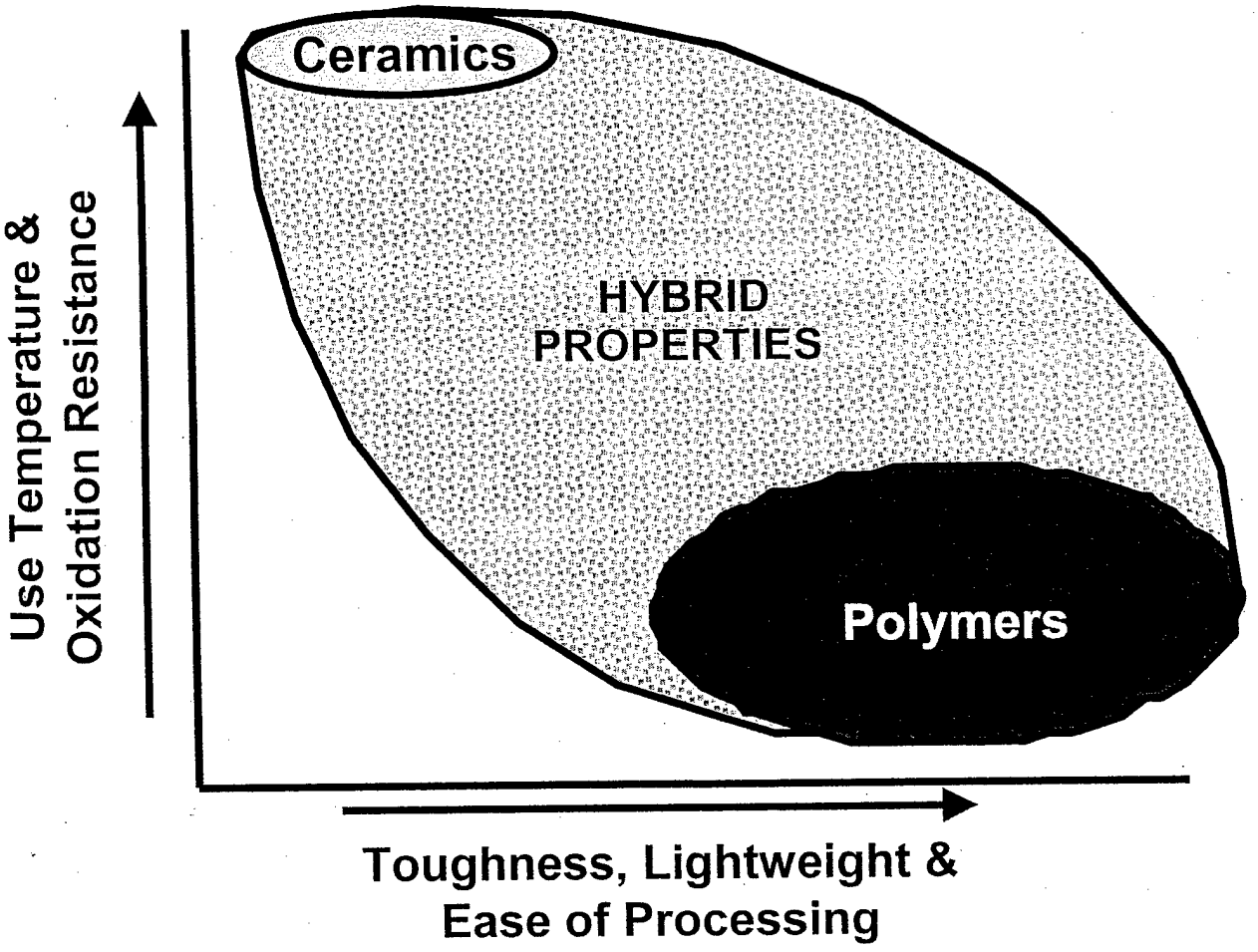
Objectives

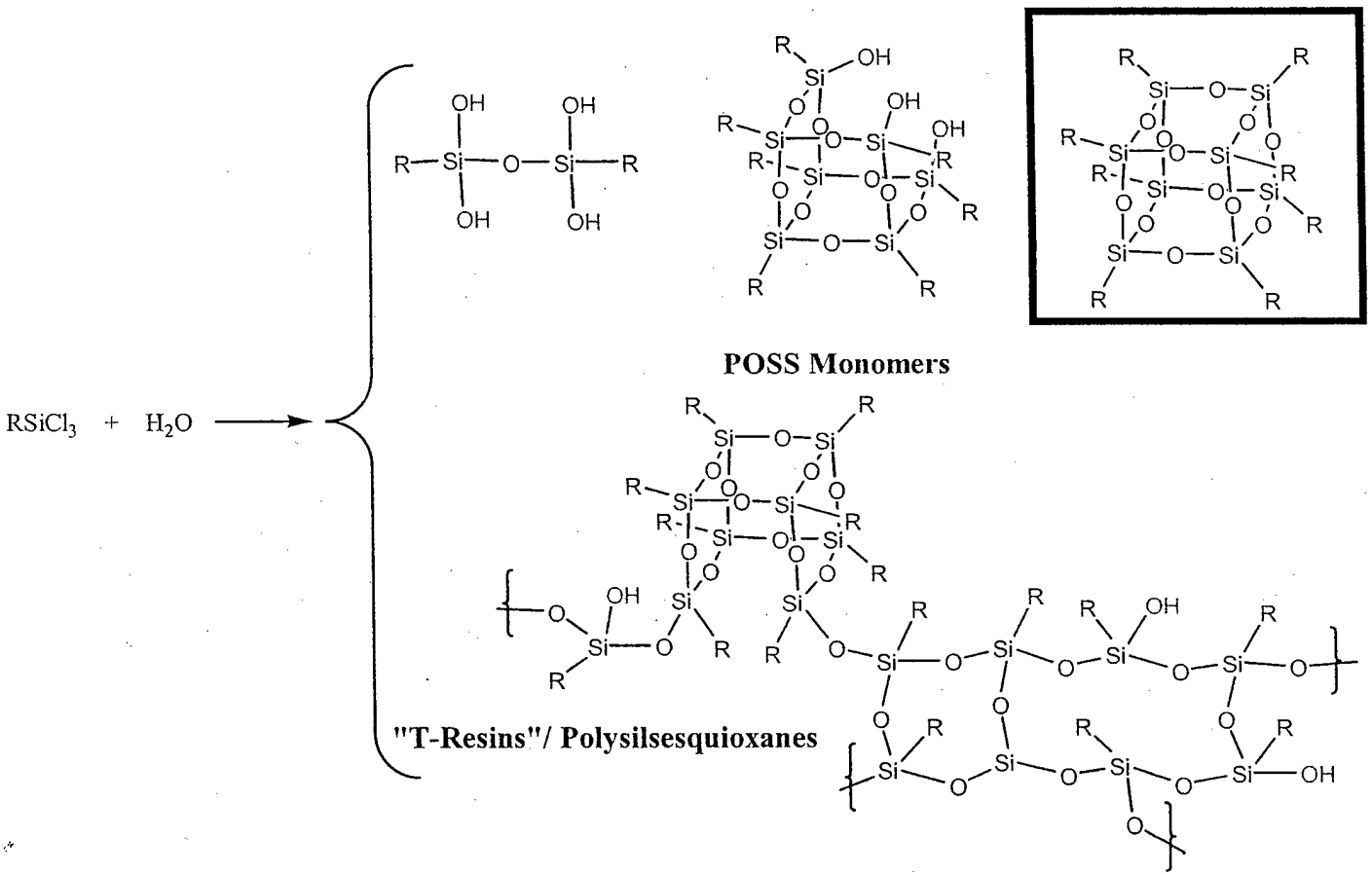
- Introduction
- History of our SRM program: Early Work
- In-House efforts
- POSS in EPDM Results
- Future of the Program

Propulsion (Air Force) Technology is Limited by Material Properties



- Hybrid plastics can bridge the barrier between ceramics and polymers

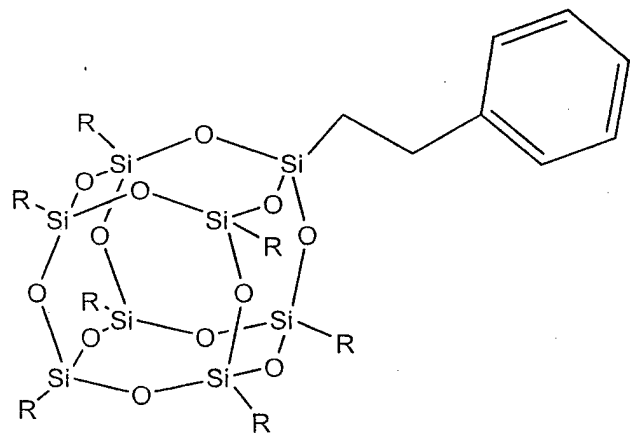
POSS
Polyhedral OligoMeric Silsesquioxane

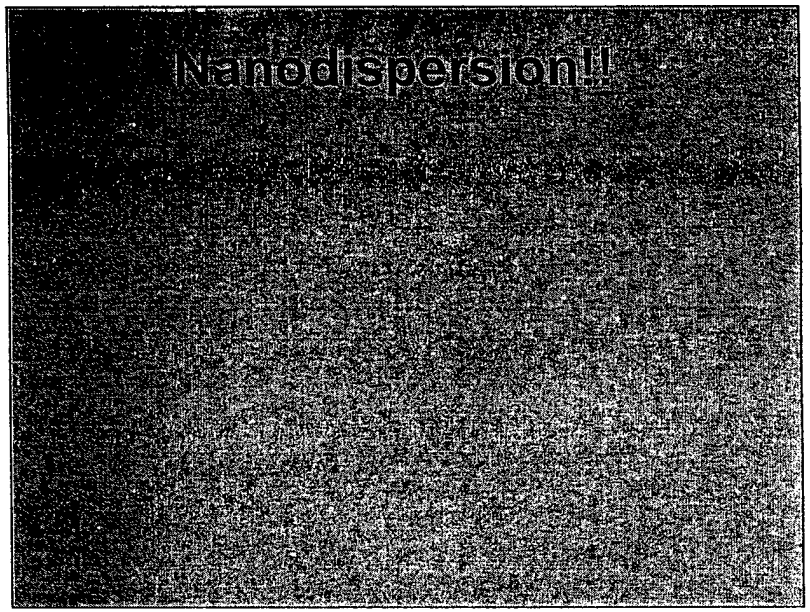


- The maximization of property enhancements in polymers results from interaction at the nano-level (Edwards AFRL/PRSM ---> POSS monomers)[4]

POSS-Polymer Blends
Miscibility Demonstrated

50 wt % Phenethyl$_8$T$_8$ in 2 million mol. wt. Polystyrene

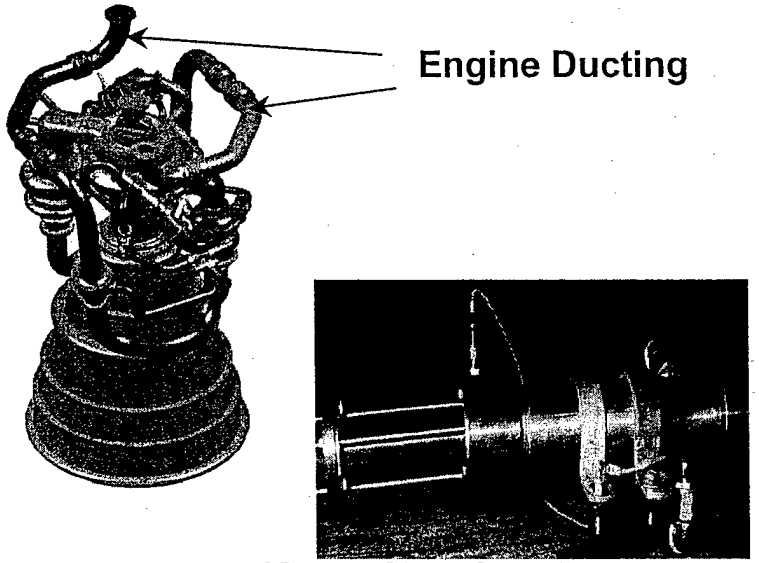




- **Catalytic hydrogenation of Styryl$_8$T$_8$**
- **No POSS crystallites by SEM or X-ray!!**

Versatility of POSS
Blends and Lubricants

Liquid Rocket Engines



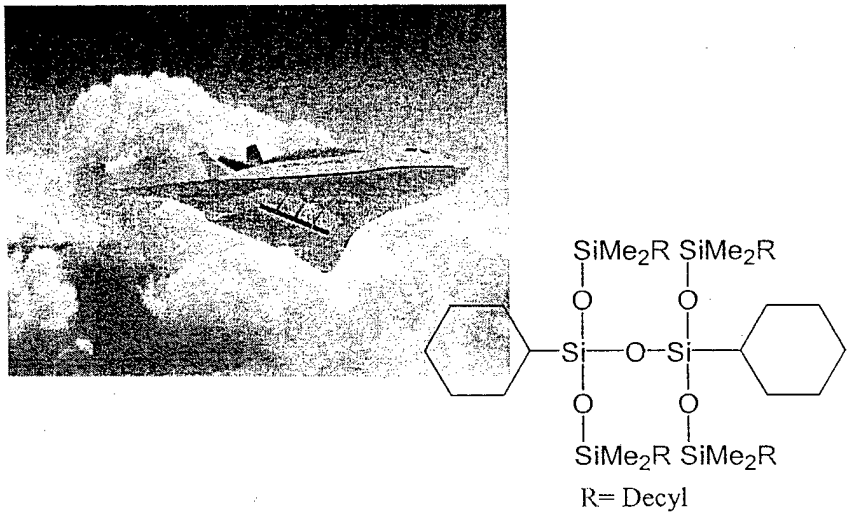
Polymer Tube/Case Hot Gas Burst Tester

Plastic Engine Ducting (SSME)

- 80% duct weight decrease
- 15% upper stage thrust-to-weight increase

3 candidates selected, SBIR, DUS&T

Lubricants



Lubricants for Turbine Engines

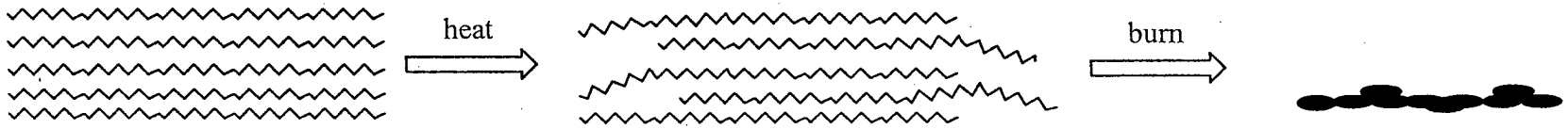
- Demonstrated to be pourable between – 40 °C and 200 °C

"pourable" is one word

Higher Temperature Studies underway (PRTM)

POSS for Ablative Materials

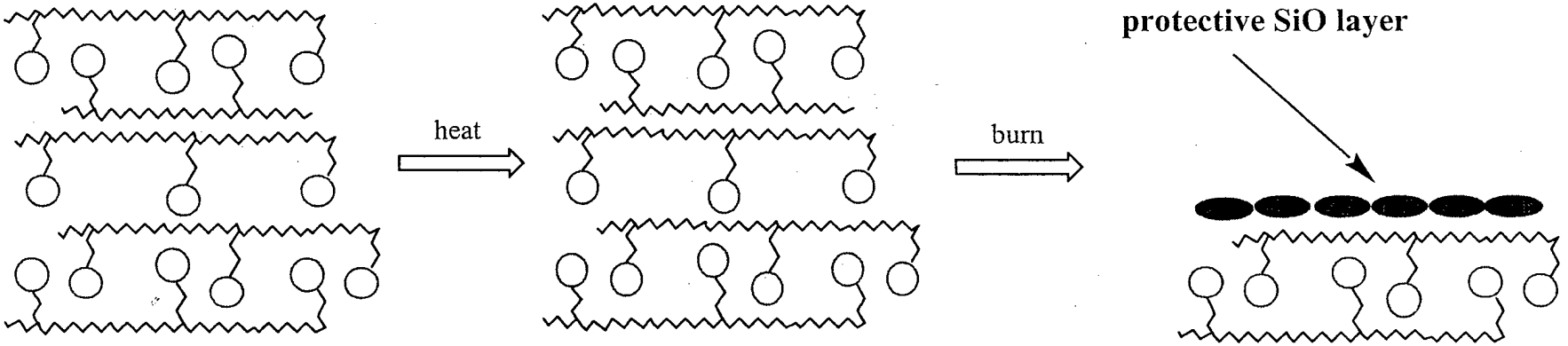
Traditional Polymer



polymer melt

carbon soot

POSS Polymer



increased melt temp

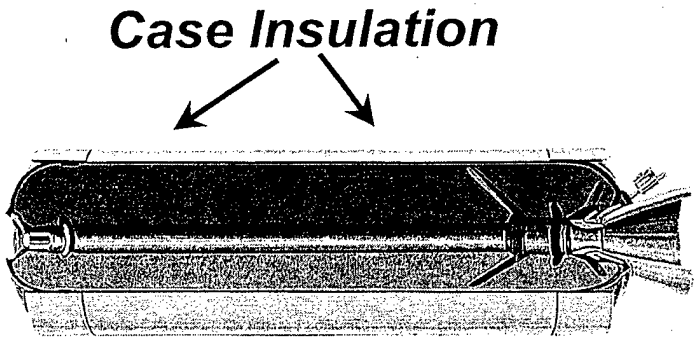
Solid Propellant Insulation Program

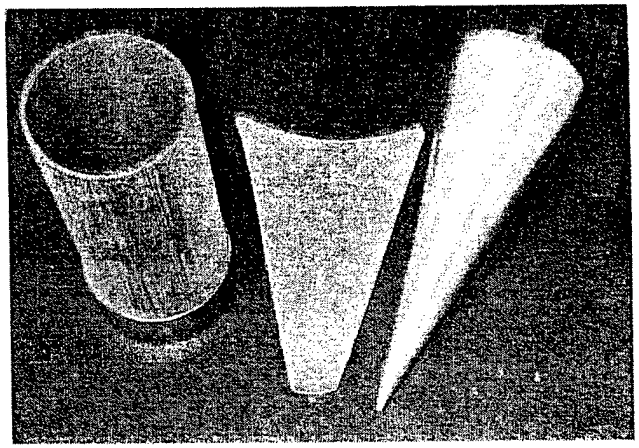
POSS- Polymers

POSS-Polymer Insulation - Advantages:

- High loadings of POSS can be incorporated without embrittlement
- Si to O ratio is 1:1.5, proven to oxidize up to 1:2 (SiO2)
- Tailorability of POSS monomers improve physical/mechanical properties
- Capabilities for Large and Small scale testing (Hybrid Plastics)

Solid Propellant Insulation Program
Project Goals 6.2 (IHPRPT)





POSS-Insulation Sample

Goal: 50% Lower Erosion of Insulation (44 % weight reduction, 7.4% booster payload increase) – Phase III IHPRPT

Objective: Development of Ceramic Forming Polymer

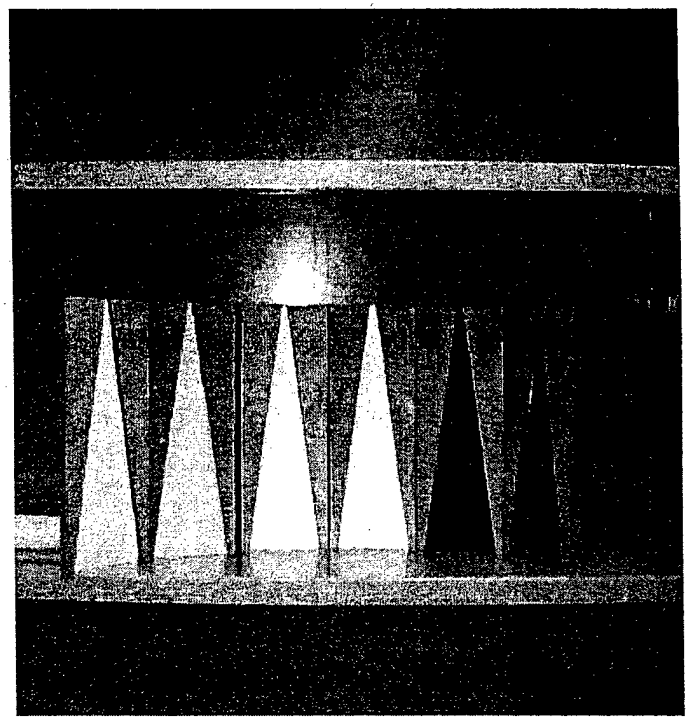
Solid Propellant Insulation Program

In-House Project History

- 1992: Flame testing performed on POSS-PDMS bead polymers. Potential for SRM insulation recognized
- 1994-1998: 4" Pi-K motor testing begun. Due to equipment limitations, a two dimensional test was designed.
- 1999- present: 3-dimensional cone testing capability acquired. Polymer blending equipment and 24 ton press acquired. Firings begun.

Solid Propellant Insulation Program

In-House Project History 1994-1998



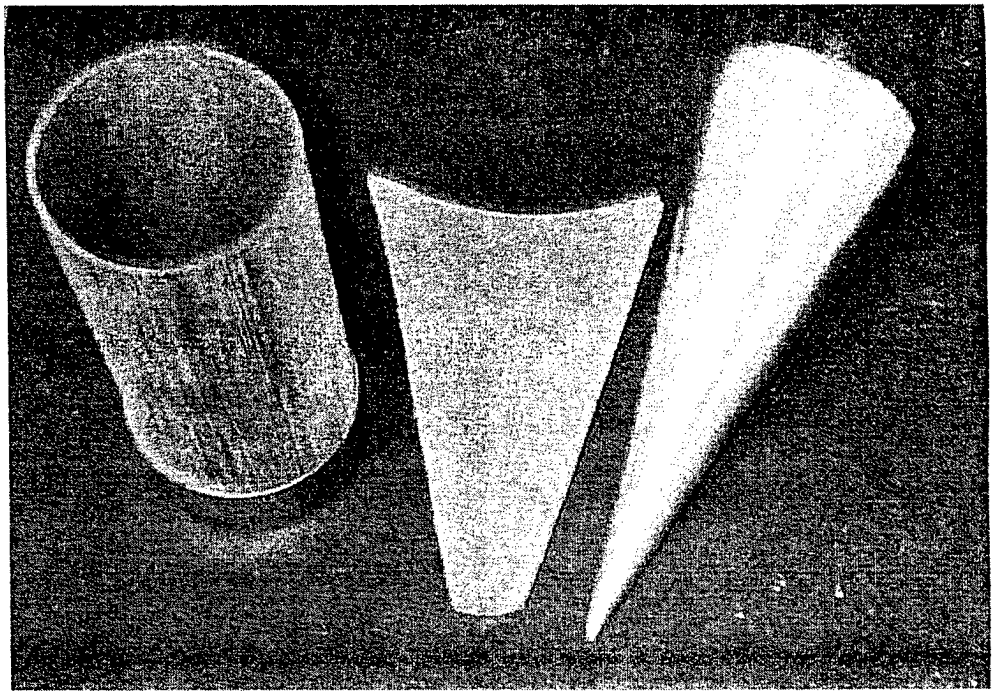
2-D pizza wedges glued into ½ cones

- Sample preparation was difficult: dissolve POSS and polymer in solvent, evaporate and press into wedge in small press
- Glue sample and standard into test bed (½ cone) and fasten together
- Samples: Pebax, BMI, Parmax, Starfire w/mat

Solid Propellant Insulation Program

In-House Project History 1999-Present

- 3-dimensional testing capability realized
- Sample preparation was streamlined: POSS is blended into polymer with standard industrial blending equipment (Brabender Mixer) and pressed into Large Pizza wedge (24 ton Press)
- Glue sample and standard into cone

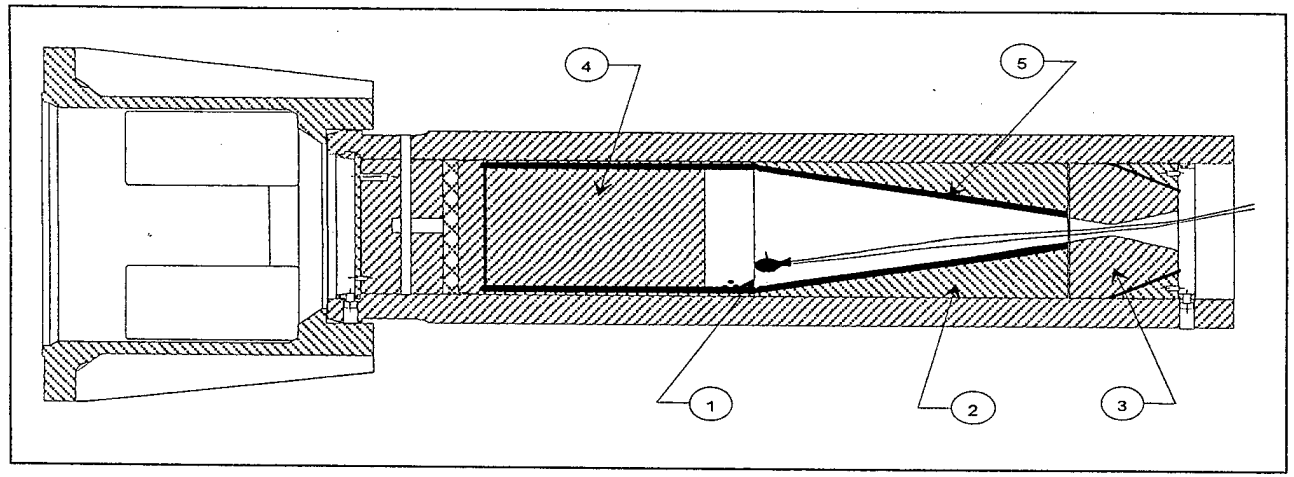


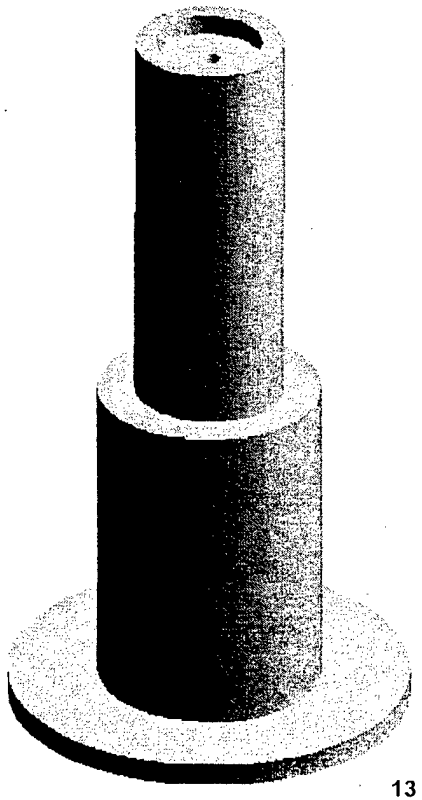
Cone, Pizza Wedge and Jig to set wedges in cone

Solid Propellant Insulation Program
In-House Low Cost Screening of New Materials

Present Capabilities:

- Test facilities developed at Edwards AFRL (4" Pi-K Motor)
- Only 100 g of material needed (down from 5 Kg)
- Cost (synthesis, part fabrication, ablation test, analysis) reduced to ~1K!!
- Rapid testing of 5-6 samples per day.





In-House SRM Insulation Testing

Interdisciplinary Team Effort

Many Diverse Skills at AFRL Come Together:

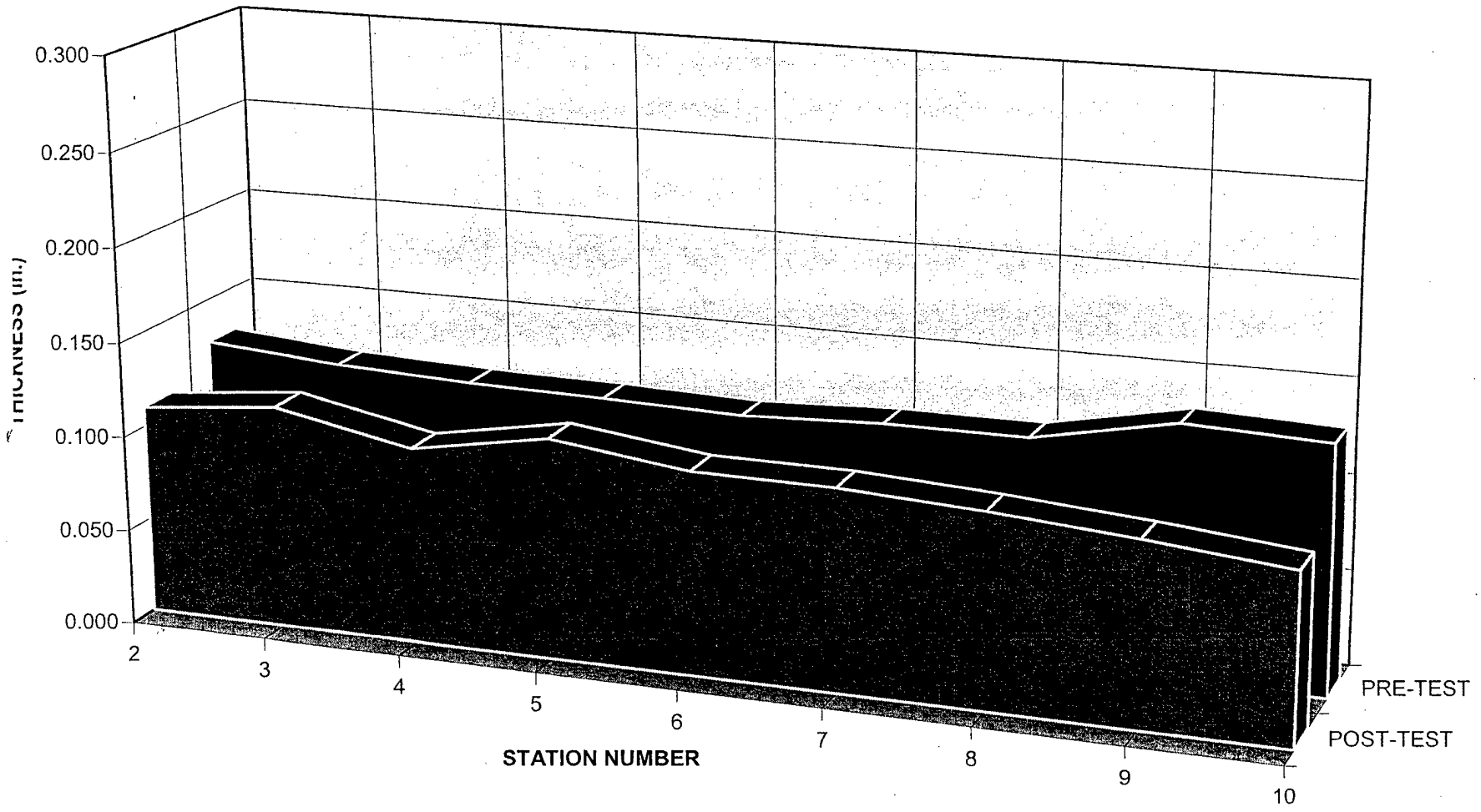
- Phenolic cone Fabrication: Machine Shop
- Pi-K Motor preparation: Propellants Branch
- Pi-K Motor Cutting: Machine Shop
- Sample Cone Preparation: Polymer working Group
- Sample Firing: Propellants Branch
- Sample Analysis: Polymer Working Group (measurements) and Motors Branch (mass flux conversion)

In-House SRM Insulation Testing

Low Cost Screening of New Materials

CHAR-063 ABLATION

(S10 - EPDM / Kevlar STANDARD)

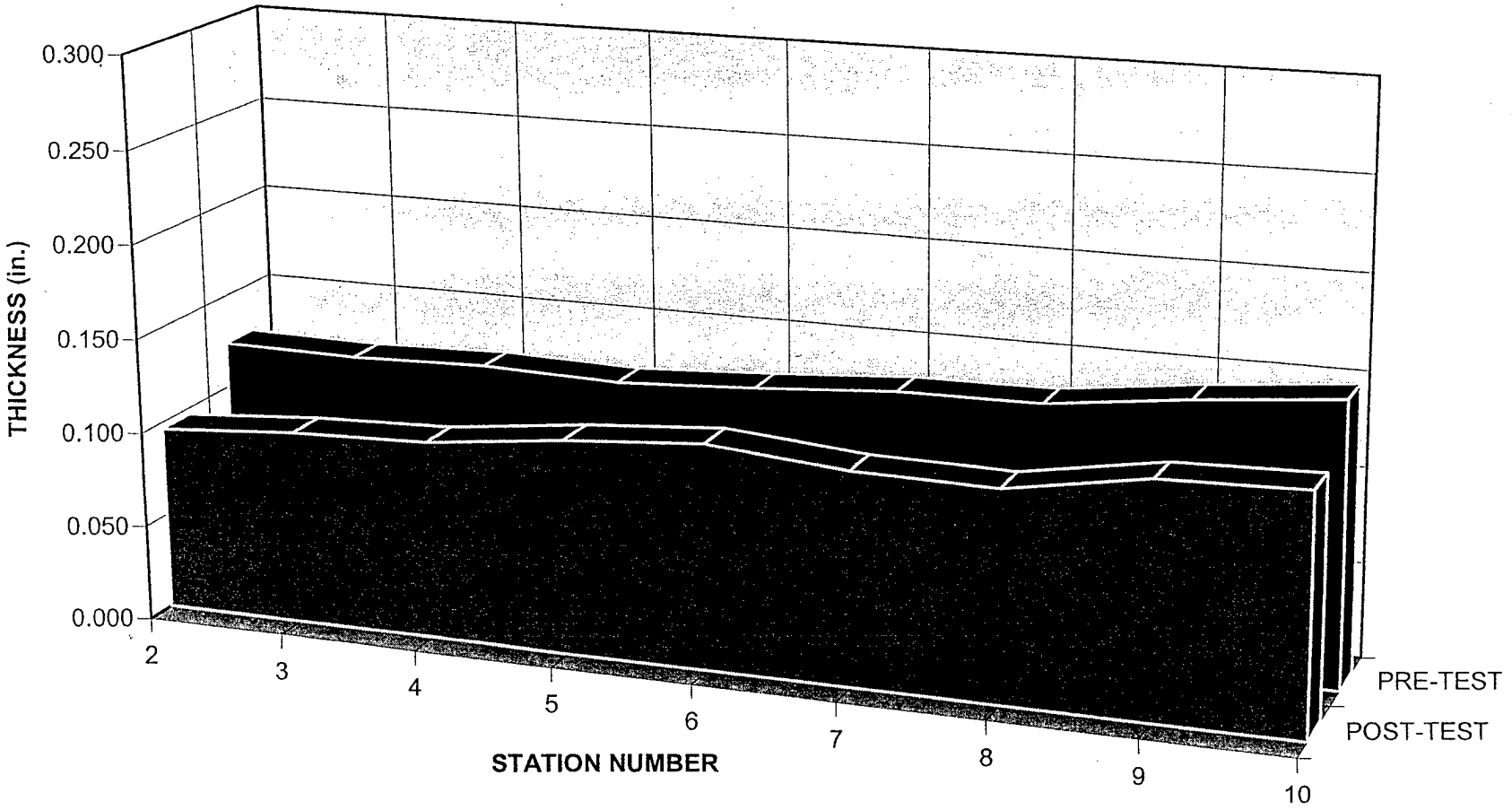


In-House SRM Insulation Testing

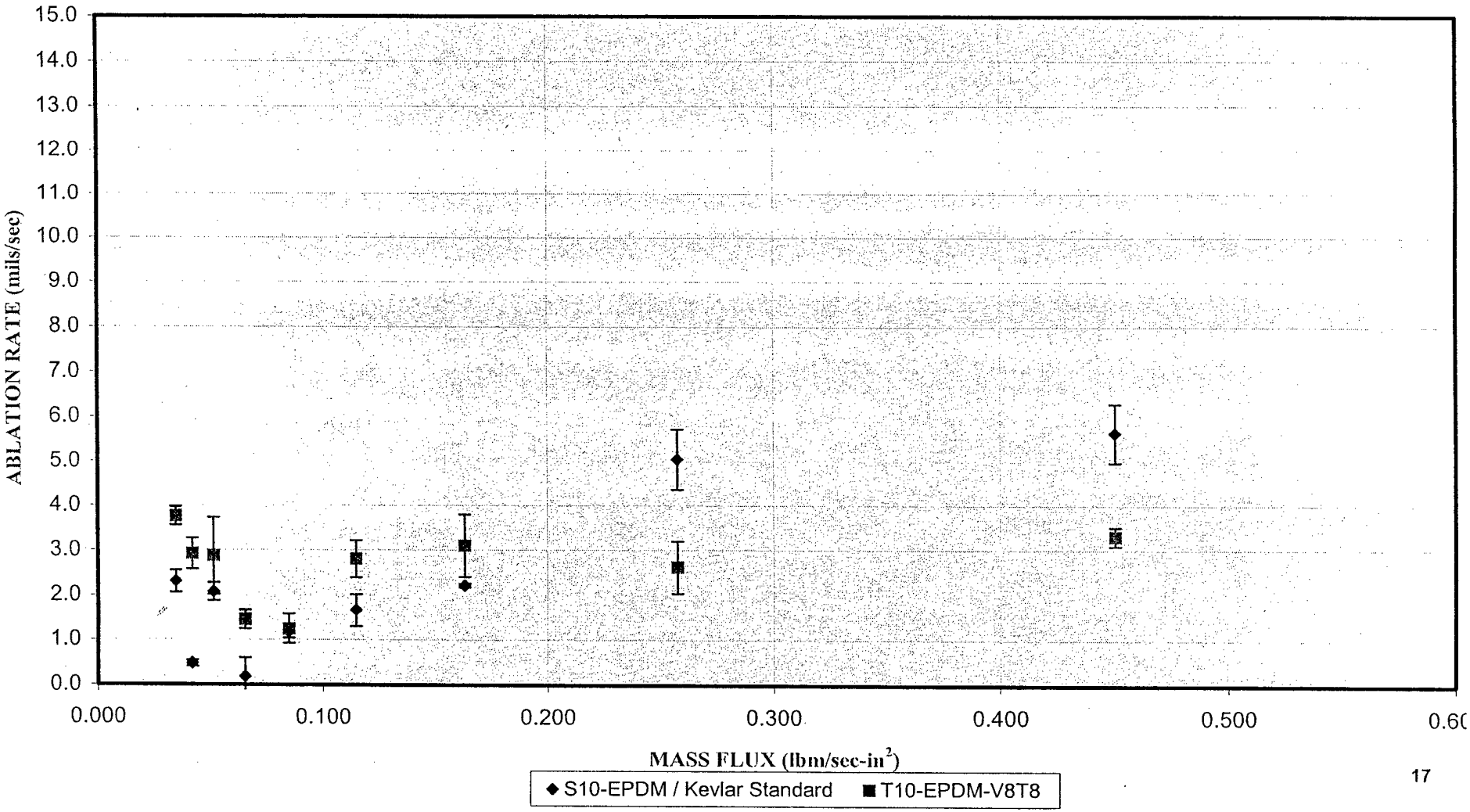
Low Cost Screening of New Materials

CHAR-063 ABLATION

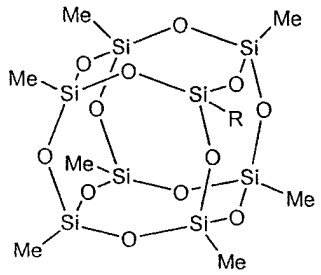
(T10 - EPDM/V_8T_8)

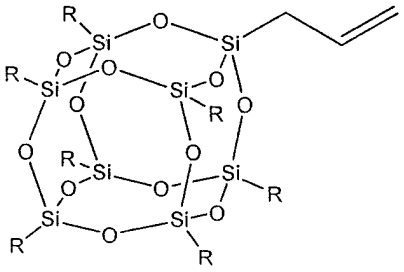


In-House SRM Insulation Testing
Ablation Rate Decreased when Using POSS

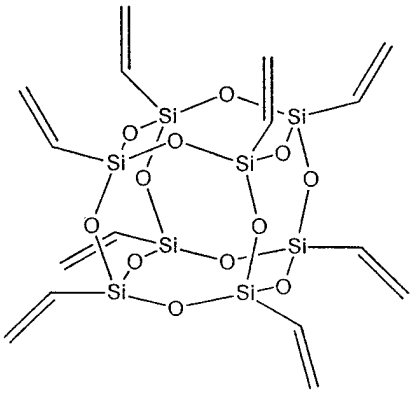


SRM Insulation Testing Program
Comparisons of POSS in EPDM





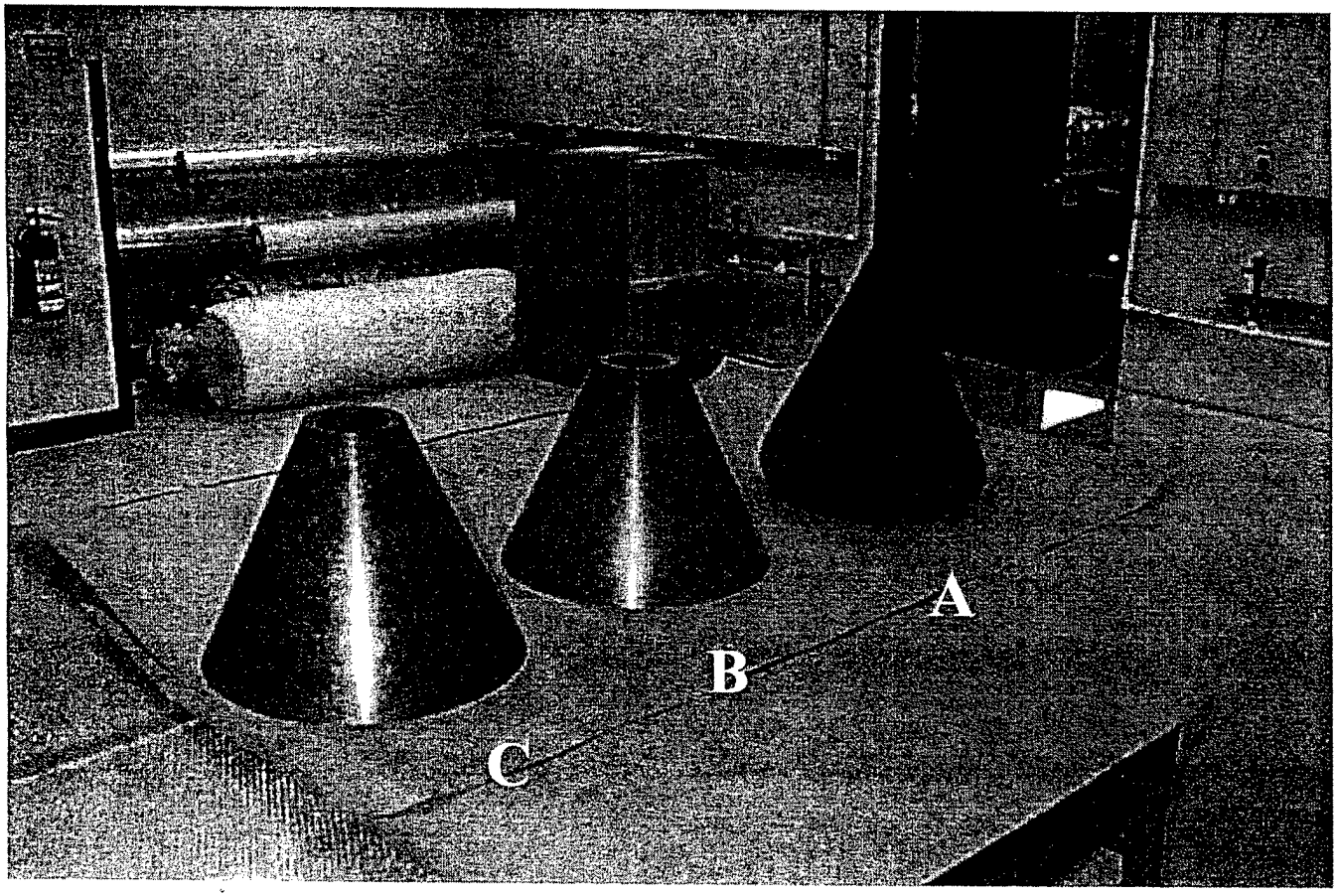
R = cyclopentyl

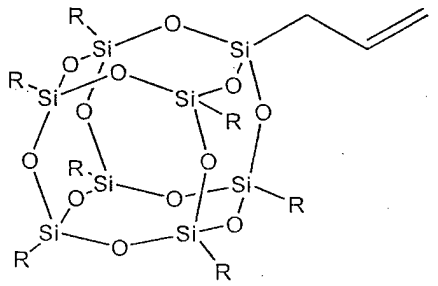


At 50 wt% loadings relative to a proprietary baseline material

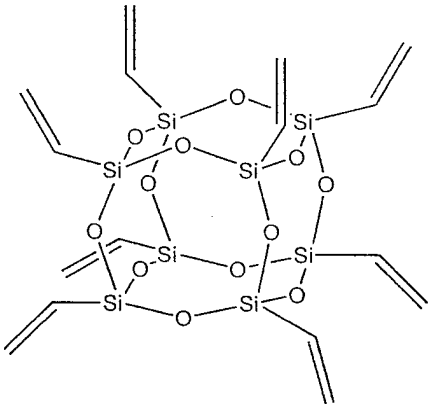
Hardness:	15%↑	no change	17%↑
Tensile:	5%↓	27%↓	1%↓
Elongation:	no change	no change	no change
Viscosity:	35%↓	21%↓	36%↓
Density:	15%↑	3% ↓	12%↑

SRM Insulation Testing Program
Convergent Cone Testing





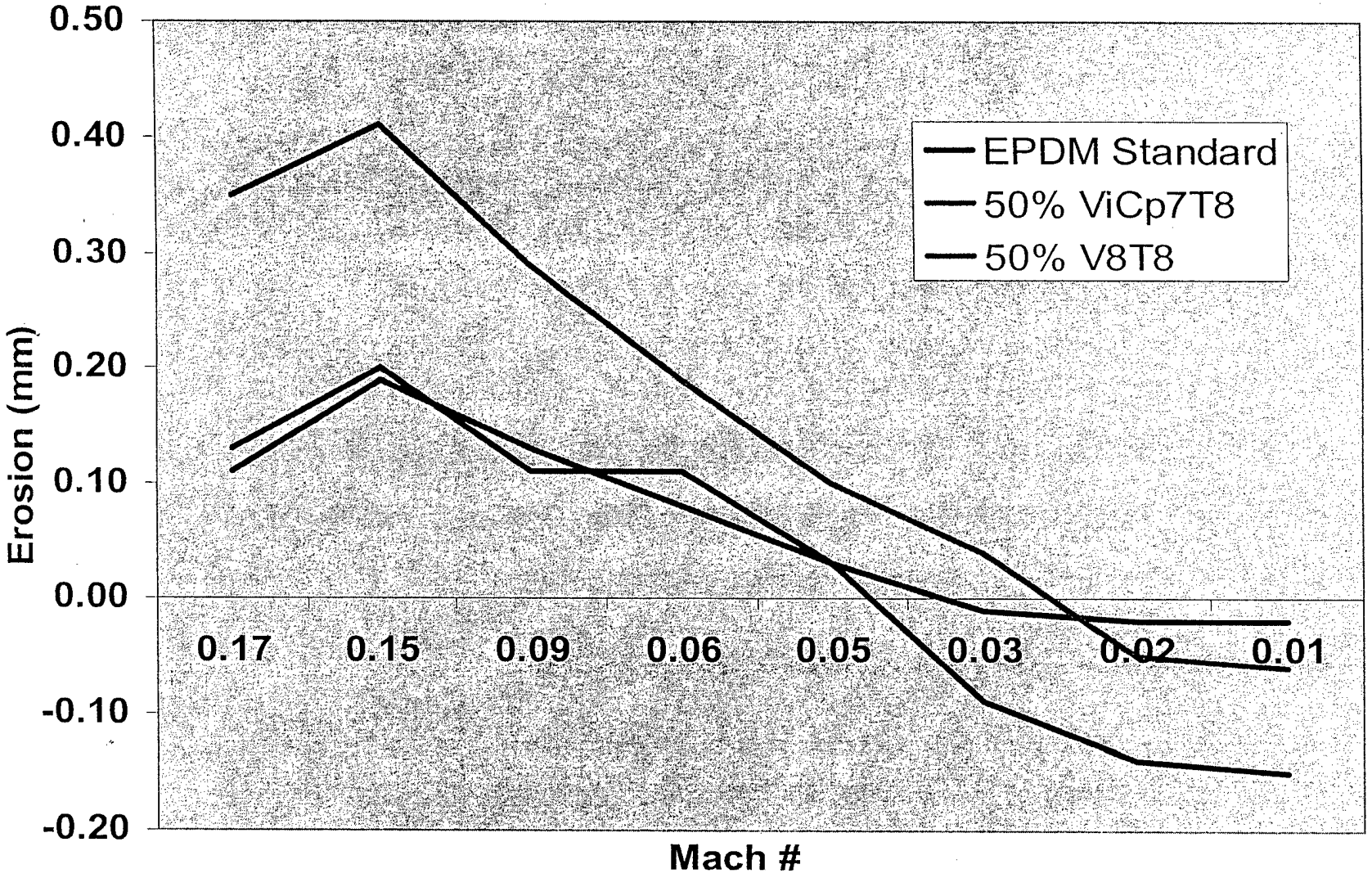
R = cyclopentyl



A) Insulation containing POSS monomers
B) Convergent Cone
C) Convergent Cone + Insulation

SRM Insulation Testing Program

Convergent Cone SRM Insulation Tests



Negative numbers represent formation of structural char

SRM Insulation Project
What Comes Next?

- More detailed physical testing of insulation
- Multiple sample cone tests
- 50 Firings Planned for FY '02

SRM Insulation Project
Multiple sample/cone

- Presently we are running the tests with two wedges in the cone: a standard and a test sample
- After the test, the cone is cut in half and measurements are taken
- It may be possible to glue in four samples/cone and still get accurate data (3 samples/1 standard)
- Working out the Logistics of multiple samples and Initial Testing is underway
- Payoff- TRIPLING OF SAMPLE OUTPUT

SRM Insulation Project
Future testing

- Thermal Property testing
- - density
- - specific heat
- - thermal conductivity
- SEM analysis before and after
- Char analysis (elemental analysis)

Conclusions

- We have all the equipment we need for the rapid testing of Solid Rocket Motor insulation
- Initial Testing in the In-House Pi-K motor tests are promising
- Initial Testing with our Partner on a larger scale also looks promising
- Plans for Future Work (multiple samples, physical testing, sample firings) are underway

In-House SRM Insulation Testing
Acknowledgements

- Mr. Hieu Nguyen (Firing Engineer; Sample Analysis)
- Dr. Tom Hawkins and Greg Warmouth (Motor Firings)
- Mr. Phil Counts (Machine Shop)
- Mr. Pat Ruth (Sample Preparation, measurement)
- Drs. Steve Svejda and Shawn Phillips (Moral Support)